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Application for Containment Zone for the Livermore Site Hydrocarbon Impacted Zone at Treatment Facility F

July 1996

Technical Editors

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Summary

The residual fuel hydrocarbon (FHC) plume in ground water in Hydrostratigraphic Unit 3 (HSU-3) in the Treatment Facility F (TFF) Area at Lawrence Livermore National Laboratory (LLNL) meets all criteria for the establishment of a Containment Zone (CZ) under the San Francisco Bay Regional Water Quality Control Board policy. We propose changing the point of compliance with Maximum Contaminant Level (MCL) cleanup goals from the residual FHC plume to downgradient wells GSW-266 and GSW-009, and crossgradient well GSW-008. Data collected at the site demonstrate the following:

- Almost seven years of remedial actions have significantly removed FHCs from the sediments and ground water.
- Mass removal rates of FHCs from ground water and FHC concentrations have significantly diminished.
- Intrinsic biodegradation will continue to degrade, contain and reduce the residual FHC plume.
- No rebound of FHC ground water concentrations was observed following a six-month shutdown of TFF.
- No other appropriate or cost-effective technologies exist that might significantly accelerate cleanup of this residual plume.

Based on the data summarized in this report, passive biodegradation is a viable treatment alternative for remediation of the residual FHCs in HSU-3 at TFF. No additional remedial actions are warranted for the FHC plume. The proposed CZ would include wells within and immediately adjacent to the residual FHC ground water plume. Establishing the downgradient plume boundary wells as the compliance points for achieving MCLs will allow intrinsic microbial activity to continue to contain and degrade the FHC plume (bioattenuation). The proposed Contingency Plan will ensure that the risks posed by the residual plume are contained and managed.

Low levels (20-60 parts per billion [ppb]) of chlorinated solvents are also present in ground water from several wells within the proposed CZ. Outside the proposed CZ, elevated concentrations of volatile organic compounds (VOCs) are in HSU-3 as well as HSUs 4 and 5 (hundreds of ppb total VOCs). The request for CZ presented in this report addresses the FHC ground water plume within HSU-3 only. Chlorinated solvents in ground water in the TFF Area will be remediated as described in the LLNL Livermore Site Record of Decision (U.S. Department of Energy, 1992) and Remedial Design Report No. 2 (Berg et al., 1993). Consequently, the occurrence, distribution, and remediation of chlorinated solvents in TFF ground water are not discussed further in this report.

1. Background and Introduction

This report presents the documentation and rationale for establishing a Containment Zone (CZ) at the Lawrence Livermore National Laboratory (LLNL) Livermore Site for the hydrocarbon-impacted water-bearing zone, Hydrostratigraphic Unit 3 (HSU-3), in the Treatment Facility F (TFF) Area (Fig. 1). We have evidence that passive bioremediation will continue to degrade and contain the residual fuel hydrocarbons (FHCs) in HSU-3, and that CZ status should be granted for FHCs in HSU-3 at TFF. Chlorinated solvents in ground water in the TFF Area will be remediated as described in the LLNL Livermore Site Record of Decision (ROD) (U.S. Department of Energy [DOE], 1992) and Remedial Design Report No. 2 (Berg et al., 1993). Consequently, the occurrence, distribution, and remediation of chlorinated solvents in TFF ground water are not discussed further in this report.

The first portion of this report presents the background of previous investigations, summarizes remedial treatments that have been fully implemented at TFF, and describes a recent investigation establishing that passive bioremediation is a viable treatment alternative for the residual FHC plume. The latter portion of this report demonstrates how the site meets each of the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) interim guidance criteria for establishing a Category II CZ (Ritchie, 1994; State Water Resources Control Board, 1996).

As discussed in the ROD, cleanup goals for the ground water are Maximum Contaminant Levels (MCLs) in all wells. However, the SFBRWQCB has recently recognized that these goals may not be technologically or economically viable with current ground water remediation technologies at some sites, even after an approved cleanup program has been fully implemented (Ritchie, 1994; State Water Resources Control Board, 1996). In these cases, a CZ is an option to further manage the remaining contaminated ground water to protect human health, the environment and beneficial water uses. At sites meeting certain criteria, the SFBRWQCB has concluded that containing the residual plume and designating the downgradient site boundary or downgradient wells as the point of compliance, is a more reasonable and appropriate approach. In addition, a recent report "Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tanks" (Rice et al., 1995a), concludes that passive bioremediation should be used as a viable treatment alternative for sites where hydrocarbon source removal has been accomplished.

Site History. Between 1952 and 1979, a records review indicated that about 17,000 gal of gasoline may have been lost from the southernmost of four U.S. Navy era underground storage tanks at the current location of TFF (Nichols et al., 1988). The apparent inventory deficit is suspect because the measurement accuracy is not known and undocumented removal of gasoline may have occurred. All four tanks were removed from service, drained of gasoline, and filled with sand in 1980 (O.H. Materials, 1985).

Investigations. The local hydrogeology and the subsurface distribution of FHCs has been studied extensively. Drilling and sampling of soil borings and monitor wells began in the TFF Area in 1984 (Carpenter, 1984). To date, a total of 98 soil borings have been drilled and sampled within and immediately adjacent to the TFF Area (Carpenter, 1984; O.H. Materials, 1985; Dresen et al., 1986; Nichols et al., 1988; Isherwood et al., 1990; Cook et al., 1992; Newmark, 1994). HSU-3 well locations in the central portion of the TFF Area are shown in Figure 2.

Between October 1991 and September 1993, an extensive subsurface characterization of the TFF Area was conducted (Bainer and Bishop, 1995) to assist in the design of a novel thermal remediation technique known as the Dynamic Underground Stripping (DUS) Demonstration Project. Thirteen hydrogeologic and hydrogeochemical cross sections were constructed by integrating data from geologic descriptions of continuously cored boreholes at TFF (Appendix A), geophysical wireline logs of the boreholes, chemical analyses of the sediments from cored intervals, and data from two long-term hydraulic tests (over 24 hours), one 9-hour, and one 7-hour test (Table 1). The cross sections were used to prepare structure, isopach, and isoconcentration maps of the gasoline contaminated subsurface and to estimate the volume of FHCs present.

Table 1. TFF Area long-term hydraulic tests.

Well	Test type and duration (hr)	Date	HSUs evaluated
GSW-6	Constant flow rate (72)	June 1987	HSUs 2, 3, 4, 5, 6
GEW-710	Step drawdown (9)	February 1991	HSU 3
GSW-16	Constant drawdown (100)	December 1990	HSUs 3, 4, 5, 6
GEW-816	Constant flow rate (7)	August 1992	HSU 3

Subsequently, additional hydrogeologic analyses have been conducted on a larger scale across the entire Livermore Site and integrated to establish the hydrostratigraphy of all contaminant-bearing ground water zones. These regional interpretations established the identification of seven HSUs at the LLNL Livermore Site (Fig. 3). An HSU is a sequence of sediments defined on the basis of its geologic, geophysical, chemical, and hydraulic properties. Constituent permeable zones within HSUs are hydraulically interconnected as evidenced by hydraulic testing. Isoconcentration, isopach, and potentiometric maps for each individual HSU are currently being used to design, monitor, and optimize remedial wellfields at each treatment facility area across the Livermore Site. Extensive soil and ground water chemical data indicate that gasoline contamination is now limited to HSU-3. The regional hydrostratigraphy of the TFF and adjacent areas was determined subsequent to the design of the ground water extraction wellfields presented in "Remedial Design Report No. 2 for Treatment Facilities C and F" (Berg et al., 1993a).

HSU-3 was further characterized and divided into three lithologic zones for the DUS project (Fig. 4) (Bainer and Bishop, 1995). This very detailed study covered the area shown in Figure 2. HSU-3 contains an upper permeable layer called the "upper steam zone," a low-permeability layer of fine-grained sediments called the "confining layer," and a lower permeable layer called the "lower steam zone" (Fig. 4). The upper steam zone and the confining layer compose HSU-3A, and the lower steam zone is HSU-3B.

The upper steam zone consists of a heterogeneous mixture of high to moderate permeability, sandy to clayey gravel and gravely to silty sand deposits, and varies from 0 to over 30 ft thick. The top of the zone is found at depths ranging from about 75 to 95 ft below ground surface (bgs) and its base ranges from depths of about 95 to 110 ft bgs. Only the lower few feet of this zone are currently below the water table. The confining layer, which consists of clayey silt to silty clay, varies in thickness from less than 6 ft in the south to over 26 ft in the northern part of the TFF

Area. The confining layer separates the upper steam zone from the lower steam zone (HSU-3B). Unlike the upper steam zone, the lower steam zone consists of a single, discrete unit composed of higher permeability, coarse-grained, sandy gravel to gravely sand. The top of the lower steam zone is found between about 112 and 130 ft bgs, and varies between 7 and 19 ft in thickness. The two long-term hydraulic tests on wells GSW-006 and GSW-016, a 9-hour test on well GEW-710, and a 7-hour test on well GEW-816 indicate that there is no hydraulic communication between wells screened in HSU-3 and wells screened in HSUs 2, 4, 5, or 6 (Table 1).

Chemical analyses of sediments and ground water were used to define the vertical and horizontal extent of FHCs in the TFF Area. Early investigations determined that most of the fuel was contained in a 30 ft-diameter roughly cylindrical area between the depths of 20 and 140 ft (O.H. Materials 1985; Nichols et al., 1988). Both free-phase and dissolved gasoline constituents were in sediments and ground water above and below the water table. Free-phase gasoline below the present day water table is attributed to a 10- to 30- ft lower water table during the time of the release (Alameda County Flood Control and Water Conservation District, 1982). As the water table rose in the 1980s, free-phase gasoline was trapped within and against the fine-grained, low-permeability sediments forming the confining layer between the two steam zones (Nichols et al., 1988). FHCs are therefore considered to have migrated through the confining layer separating the two zones under unsaturated conditions during the period when the water table was located within the lower steam zone.

Prior to remediation, benzene concentrations exceeding 10 parts per billion (ppb) in ground water extended approximately 500 ft from the leak point as shown in Figures 3 and 6. Remedial activities have been ongoing at TFF for almost seven years, and the areal extent and concentration of the FHC plume has dramatically decreased. Currently, benzene concentrations exceeding 10 ppb in ground water are restricted to within approximately 50 ft of the leak point (Figs. 5 and 7). Current benzene concentrations in TFF HSU-3 wells within the proposed CZ are presented in Table 2. The highest concentration of benzene within the permeable portion of HSU-3 is 11.1 ppb in well GSW-216. Although elevated concentrations of benzene are present in wells HW-GP-105 (122 ppb), GEW-816 (58 ppb), and recently completed well W-1115 (2,353 ppb), the screened intervals of these wells include fine-grained, hydraulically-isolated sediments within the confining layer, between the upper and lower steam zones, and are not considered representative of HSU-3 aquifer conditions. However, it is expected that gasoline may continuously diffuse with time from the confining layer into the upper and/or lower steam zones near the point of release, but at rates and concentrations that will be easily bioattenuated. This interpretation is supported by the fact that benzene concentrations in wells completed in HSU-3 permeable sediments immediately adjacent to these wells are all below 12 ppb (Table 2). Soil chemical data from over 40 continuously-cored boreholes advanced below the base of HSU-3 indicate that no FHCs are present beneath HSU-3, about 130 ft bgs (Fig. 3).

Table 2. Recent FHC and BTEX ground water concentrations from HSU-3 wells within or adjacent to the proposed containment zone.

Well	TPH ^a (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylene (ppb)	Date analyzed
GEW-710	887	0.46	8.41	2.78	13.93	12/21/95
GEW-816	1,100	58	–	–	–	06/21/96
GIW-815	97	3.07	0.3	<0.5	3.96	12/21/95
GIW-820	149	4.45	0.4	<0.5	10.43	12/21/95
GSW-006	–	4.87	217.59	30.83	217.13	02/13/96
GSW-007	–	<0.3	<0.3	<0.3	<0.3	05/24/96
GSW-008	–	<0.3	<0.3	<0.3	<0.3	05/24/96
GSW-009	–	0.34	<0.3	<0.3	<0.3	05/24/96
GSW-013	–	<0.5	<0.5	<0.5	<0.5	02/13/96
GSW-011	–	0.56	1.1	0.51	<0.6	03/01/96
GSW-215	–	2.9	<1.0	<1.0	<1.0	06/04/96
GSW-216	1,730	11.1	3.01	0.9	0.7	12/21/95
GSW-266	–	<0.3	<0.3	<0.3	<0.6	02/13/96
HW-GP-102	<10	<0.5	<0.5	<0.5	<0.5	02/21/95
HW-GP-103	–	3.16	<0.5	<0.5	2.8	02/13/96
HW-GP-104	–	0.65	<0.3	<0.3	9.2	05/31/96
HW-GP-105	–	121.88	5.59	29.06	86.72	02/13/96
W-1115 ^b	61,400	2,353	5,699	3,139	5,157	12/21/95

^a Total petroleum hydrocarbons.^b Completed only in low-permeability sediments within the confining layer between the upper and lower steam zones.

2. Remedial Actions

A series of remedial actions have been implemented at TFF. These treatments are discussed briefly below and summarized in Figure 8. Additional details concerning the history and results of the remedial techniques tested at TFF are described in LLNL's Annual Ground Water Project Reports (Dresen et al., 1989; Dresen et al., 1990; Devany et al., 1990; Macdonald et al., 1991; Devany et al., 1992; Hoffman et al., 1993; Hoffman et al., 1994; Hoffman et al., 1995) and in several documents summarizing specific remedial treatments (Isherwood et al., 1990; Cooke et al., 1992; Sweeney et al., 1994; Newmark, 1994).

1988 to 1992. TFF subsurface remediation began in 1988 with vacuum-induced soil venting and use of a gasoline skimmer to remove free product from the top of the water table during pumping tests and routine sampling. Approximately 2,200 gal of liquid-equivalent gasoline vapor were removed between September 1988 and December 1991 (Cook et al., 1992), and from 1988 to June 1990 approximately 100 to 150 gal of free-product FHCs were removed by skimming (Isherwood et al., 1990).

1993. Experimental application of DUS, a thermal remediation technique, was conducted during 1993 at TFF. This method used three integrated technologies: steam injection to heat the subsurface and drive volatile compounds toward the extraction wells; electrical heating to release sorbed contaminants from clay and fine-grained sediments by volatilization into the steam zones; and an aboveground treatment facility, TFF, to treat hot extracted vapors and ground water containing high FHC concentrations (Fig. 4).

Following DUS, the Accelerated Removal and Validation project (ARV) was piloted at TFF to test system optimization strategies while taking advantage of the heated subsurface to enhance the FHC removal rate. No steam was injected during ARV. Instead, ground water drawdown was maximized exposing normally saturated sediments to vapor flow, thereby increasing hydrocarbon removal. A modified electrical heating grid was operated in an effort to enhance volatilization of the FHCs.

The first full-scale test at TFF was extremely successful. During 21 weeks of operation over the course of one year, the DUS/ARV technique removed approximately 7,500 gal of gasoline trapped in soil both above and below the water table. Approximately 100,000 cubic yd of soil were beneficially influenced (Newmark, 1994). DUS/ARV were terminated when FHC removal efficiency diminished and funding was exhausted. Post-DUS drilling occurred before the ARV treatment (Bainer and Bishop, 1995). Sampling of six boreholes after DUS treatment demonstrated a dramatic decrease in the remaining gasoline plume. Most residual gasoline was located in the relatively thick areas of low-permeability sediments that make up the confining layer. DUS/ARV treatment appears to have removed all of the available free product. Any residual-free product would have to be greatly isolated from the permeable portions of the formation to have survived the remedial treatments and remain undetected. The elevated concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) recently found during the drilling of well W-1115 are interpreted to represent such an instance. However, it is expected that gasoline may continuously diffuse with time from the confining layer into the upper and/or lower steam zones near the point of release, but at rates and concentrations that will be easily bioattenuated. DUS results are presented in Newmark (1994), and the ARV results are described in Sweeney et al. (1994).

1994 to Present. Beginning in January 1994, post-DUS remediation consisted of continued vapor and ground water extraction with aboveground treatment at TFF. Ground water was remediated via ultraviolet oxidation and air stripping, while extracted vapors were oxidized in an internal combustion engine. During post-DUS remediation (1994–1995) TFF continued to treat diminishing quantities of FHCs in extracted vapor and ground water (ground water data is presented in Fig. 9). Measured hydrocarbon concentrations in extracted vapors and ground water exhibited an exponential decline with time indicating that the majority of the hydrocarbons had been successfully recovered. Vapor phase FHC concentrations reached asymptotic low levels, and after a temporary shutdown, no rebound was measured. The same trend is observed in ground water. Following shutdown of ground water extraction at TFF between April 18 and October 17, 1995, no rebound was observed in ground water FHC concentrations (Fig. 9 and Table 3). Sampling of sediments from boreholes drilled in early July 1995 within the center of the FHC plume also demonstrated that vadose zone remediation was complete, and closure of the vadose zone at TFF was granted by the SFBROWCB, the Department of Toxic Substances Control (DTSC), and the U.S. Environmental Protection Agency (EPA) on August 17, 1995 (Attachment 1).

Table 3. TFF gasoline removal, 1995.

Month	Hydrocarbon concentration ^a		Volumes pumped		Gasoline removal (gal) ^b		
	Water (ppb)	Vapor (ppmv)	Water (gal)	Vapor (ft ³)	Water	Vapor	Totals
January	1,880	33	30,000	15,000	0.07	0.02	0.09
February	2,140	17	391,000	649,000	1.08	0.41	1.49
March	1,350	11	446,590	724,000	0.78	0.30	1.08
April	1,350	–	233,950	0	0.41	–	0.41
October	1,000	–	197,790	0	0.26	–	0.26
November	770	–	123,220	0	0.12	–	0.12
December	770	–	16,965	0	0.12	–	0.12
Totals	1,323	20	1,439,515	1,388,000	2.84	0.73	3.57

^a Flow-weighted concentration averages.^b Liquid-equivalent gal of gasoline.

Contaminant Removal Summary. Since beginning remediation of FHCs at TFF in 1988, approximately 10,000 gal of gasoline have been removed (Fig. 8). In total, approximately 17,000,000 gal of ground water have been extracted and treated, resulting in a dramatic decrease in FHC concentrations in ground water. Overall, benzene concentrations in extraction well effluent have decreased from highs of 10,000 to 22,000 ppb during the electrical preheating phase of DUS (January 1993), and highs of 8,000 ppb during the steam injection phases, to current concentrations of about 40 ppb (Fig. 9). Concentrations of FHCs in HSU-3 wells at TFF are presented in Table 2 and Appendix B.

3. Bioremediation

Prior to DUS treatment at TFF, a wide variety of microorganisms were believed to be metabolizing the gasoline and therefore degrading the BTEX components of the gasoline. Microbial studies (Krauter et al., 1992; 1994) indicated that aerobic heterotrophic microbial populations at TFF (as assayed by laboratory plating tests) were larger than those in nearby uncontaminated areas. Redox species in ground water collected at TFF, before the DUS project, also strongly indicate that significant microbial degradation of hydrocarbons was occurring in the subsurface (McNab, unpublished data). Nitrate and sulfate concentrations were significantly depleted compared to ground water from the rest of the Livermore Site, showing a peak of electron species depletion in the center of the hydrocarbon plume. These results strongly indicate that sulfate- and nitrate-reducing microorganisms were responsible for hydrocarbon degradation. These results are typical of passive biodegradation of a hydrocarbon plume.

Heating of the subsurface during DUS dramatically altered the microbial populations in the subsurface (Krauter et al., in press). Sediment temperatures reached up to 90°C creating an environment preferentially favoring the growth of heat-tolerant microorganisms known as

thermophiles. Total numbers of microorganisms were reduced up to 95% in the steamed sediments. Comparisons of microorganisms from pre-DUS and post-DUS sediments show that the indigenous species in HSU-3 sediments were very different. Gram negative *Pseudomonas* species were dominant pre-DUS, while gram positive *Bacillus* species and Fungi dominated post-DUS.

Approximately two years after thermal remediation, the saturated sediments and ground water in HSU-3 still have elevated temperatures of 40 to 60°C (ambient ground water temperature prior to DUS was about 18°C). In 1995, a study of the intrinsic bioremediation of the residual FHCs in the post-DUS environment was designed and completed to examine whether the thermophilic microorganisms present in this new high temperature environment were degrading the residual hydrocarbons (McNab et al., 1995). Despite the high temperature environment, our results show that active intrinsic biodegradation of the hydrocarbons is occurring in the subsurface. This intrinsic bioattenuation will continue to contain, degrade and reduce the residual gasoline plume over time. The rate of degradation is currently under study.

Four types of data were collected to evaluate TFF biodegradation: 1) ground water geochemistry, 2) soil microcosm studies, 3) measurement of microbial hydrocarbon metabolites in TFF ground water, and 4) measurement of BTEX and FHC concentrations in ground water in the absence of ground water extraction. Each is discussed below:

1. Inorganic ground water geochemistry in TFF Area wells was found to be characterized by a "bioremediation signature" resulting from microbial oxidation reactions involving the hydrocarbons. This signature includes depleted levels of electron acceptors (dissolved oxygen, nitrate, and sulfate) and elevated concentrations of manganese in comparison to background ground water chemical composition. Elevated bicarbonate concentrations and decreased pH, resulting from mineralization of the hydrocarbons into carbon dioxide, are also characteristic of TFF ground water. Elevated temperature may also influence bicarbonate concentrations and pH, but geochemical speciation modeling suggests that the high subsurface temperatures in TFF ground water are not responsible for the observed geochemistry.
2. The soil microcosm studies tested whether native thermophilic microorganisms in TFF sediments had the potential to degrade BTEX compounds. These experiments utilized sediments from freshly collected HSU-3 soil cores from a recent borehole that were maintained under nitrate- and sulfate-reducing conditions at 55°C. These conditions closely mimicked *in situ* conditions in the borehole. Native anaerobic thermophilic microorganisms in the sediments were able to degrade BTEX compounds.
3. Ground water from TFF wells was analyzed for hydrocarbon metabolites (Beller et al., 1995). Alkylbenzoates have been detected in the 10 to 15 ppb range in ground water samples from TFF wells. The presence of these metabolites indicates that active bioremediation is occurring.
4. Ground water BTEX and FHC concentrations were monitored in the absence of pumping and declined during the study interval. This is empirical evidence that the biodegradation rate is great enough to contain the residual contaminants as they diffuse from the fine-grained sediments over time.

4. Evaluation of Containment Zone Criteria

Based on our evidence of passive bioremediation occurring *in situ*, the site hydrogeology, the previous remedial actions implemented at TFF, and the concentrations of the residual FHC plume, DOE/LLNL recommends HSU-3 at TFF as a candidate for establishment of a Category II CZ. This site meets all of the criteria for establishment of a Category II CZ. In the following section, each of the SFBRWQCB criterion for establishment of a CZ is considered for TFF.

Category II, Criterion a. In Category II, Criterion a, an appropriate cleanup program including adequate source removal and free product removal has been fully implemented and reliably operated for a period of time, which is adequate to understand both the hydrogeology of the site and pollutant dynamics.

Remedial activities have been ongoing at TFF for seven years. As a result of these efforts, the size and concentration of the plume has been significantly reduced (compare Figs. 6 and 7). As previously discussed, a number of remedial technologies have been successfully implemented at TFF and have removed approximately 10,000 gal of gasoline. All available separate-phase hydrocarbons have been removed by extensive remediation activities at TFF since September 1988.

As described below, the hydrogeology of the site and the extent and migration potential of the plume are well understood. These efforts included an extensive subsurface characterization of the TFF Area (Bishop et al., 1995) and numerous hydraulic tests to define hydraulic communication and potential hydrocarbon migration pathways in the subsurface (Hoffman et al., 1995; Bishop et al., 1995).

Site Hydrostratigraphy, Geology, and Hydraulic Tests. All FHCs at TFF are restricted to HSU-3. The sediments in HSU-3 at TFF are alluvial, ranging from very fine silt and clay to coarse gravel, with permeabilities ranging over several orders of magnitude. HSU-3 contains a layer of variable permeability in the upper steam zone, a layer of fine-grained sediments that vertically separates the upper permeable layer in HSU-3 from the lower highly permeable lower steam zone (Fig. 4). Hydraulic testing at TFF indicates that there is no hydraulic communication between wells screened in the upper and lower steam zones in the TFF Area, and no hydraulic communication exists between HSU-3 and the underlying HSU-4 and HSU-5 (Fig. 3).

Ground Water Flow. The HSU-3 hydraulic gradient is quite flat, at approximately 0.001 ft/ft. Ground water in HSU-3 consistently flows westward to northwestward beneath the Livermore Site in the TFF Area (Fig. 10). Depth to ground water is approximately 100 ft. Seasonal ground water elevation changes of about 2 to 5 ft are known to occur at the site. There are no man-made horizontal conduits at this depth which could lead to rapid ground water migration in an unanticipated, preferred direction. HSU-3 is considered to be under confined to semi-confined aquifer conditions.

Location of Residual Plume. Benzene concentrations exceeding 10 ppb in ground water are now restricted to the immediate vicinity of the gasoline leak point and are likely to decrease significantly in all directions away from the spill center (Fig. 7). Currently, benzene concentrations above the MCL are restricted to an area within approximately 110 ft from the leak point. Concentrations of FHCs and BETX in extracted ground water from December 1992 to

November 1995 are presented in Appendix B. FHCs are not found in ground water from HSUs below HSU-3, about 130 ft bgs (Fig. 3).

Stability of Residual Plume. The areal extent of the FHC plume has dramatically decreased over time due to the remedial actions discussed above. However, the center of the plume has remained stable over the past decade. Most importantly, the plume center remained stable during the six month shutdown of the ground water extraction system while the BTEX concentrations decreased. In the absence of ground water extraction, microbial degradation is expected to continue to diminish and stabilize the plume. The projected time frame for total petroleum degradation to MCLs is not known. Research addressing this issue is on-going.

These data are consistent with the conclusions of Rice et al. (1995). Their analysis of 271 California FHC contaminated sites show that typically hydrocarbon plume lengths change slowly and tend to stabilize at relatively short distances from the FHC release site. Stabilization over time appears to result from contaminant sorption to soil particulates, volatilization and passive bioremediation of the hydrocarbons.

Category II, Criterion b. In Category II, Criterion b, ground water pollutant concentrations have reached an asymptotic level (the mass removed from the ground water is no longer significant) using appropriate technology.

As a result of the ongoing remedial activities at TFF since September 1988, all available separate-phase hydrocarbons have been removed, and residual dissolved FHC and BTEX concentrations in ground water have reached asymptotic conditions (Fig. 9). No rebound in FHC or BTEX concentrations were observed following a six-month shutdown of TFF in 1995.

Category II, Criterion c. In Category II, Criterion c, best available technologies are not technically or economically feasible to achieve further significant reduction in pollutant concentrations.

Approximately 17,000,000 gal of ground water have been extracted and treated at TFF, and all of the available separate-phase hydrocarbons have been removed. As discussed above, a series of remedial actions at TFF including conventional and innovative remediation technologies (Fig. 4) have removed as much of the hydrocarbons as is technically and economically feasible. Since 1994, the FHC mass removal rate has greatly diminished, and relatively little hydrocarbon mass has been removed. As shown in Table 3, in 1995, TFF treated approximately 1.4 million gal of ground water from extraction wells GEW-808 and GEW-816 that contained a volume-weighted average FHC concentration of about 1,323 ppb. This is equivalent to about 2.84 gal of liquid-equivalent of gasoline removed. In addition, TFF extracted about 1.4 million cubic feet (ft³) of vapor containing a volume-weighted FHC concentration of about 20 parts per million by volume (ppmv) in 1995, for about 0.73 gal of liquid-equivalent of gasoline removed. Therefore, the total liquid-equivalent of gasoline removed from the TFF subsurface during 1995 was about 3.57 gal (Table 3). As in 1994, the TFF gasoline removal rate continued to decline steadily throughout the year as recoverable gasoline remaining in the area is dramatically reduced. Therefore, continued ground water extraction is not cost effective. Currently, the residual hydrocarbons are being degraded by the native microorganisms present in HSU-3 sediments. Intrinsic biodegradation will continue to contain and reduce the mass and extent of the residual FHC plume. Further costly remedial actions are not warranted.

Category II, Criterion d. In Category II, Criterion d, an acceptable plan is submitted and implemented for containing and managing the remaining human health, water quality, and environmental risks, if any, posed by residual soil and ground water pollution.

Because the FHC concentrations in ground water are not likely to increase, human health risks associated with plausible exposure pathways, such as ingestion, are expected to be extremely limited. The nearest municipal water-supply well is approximately two miles away and ground water in the vicinity of LLNL is not used as a source of drinking water. Therefore, the risk by ingestion is insignificant.

Management Plan for Residual Risk. A plan for containing and managing the remaining risks posed by residual hydrocarbons at TFF includes: 1) continued ground water monitoring for hydrocarbons within and downgradient of the plume for a limited period of time, and 2) a Contingency Plan to be implemented if monitoring indicates significant downgradient plume migration and/or increasing concentrations in the plume. Both are discussed in the following section. There are no residential drinking water or agricultural wells screened in HSU-3 within at least a one-mile radius of the FHC plume. Locations of wells in the vicinity of LLNL can be found in the LLNL Ground Water Project Annual Report (Hoffman et al., 1995). An analysis of ecological receptors and ecological risks are presented in the Baseline Public Health Assessment for the LLNL Livermore Site (Layton et al., 1989).

Contingency Plan. This plan will ensure that the FHCs within HSU-3 in the TFF Area remain in compliance with the cleanup goals, which are MCLs for FHC constituents. FHCs are the primary contaminants of concern in HSU-3, yet low levels of chlorinated VOCs (20 to 60 ppb of primarily trichloroethylene [TCE]) are also in some wells within the residual hydrocarbon plume. Therefore, continuing ground water monitoring will include FHC and VOC analysis by EPA Methods 601 and 602.

“Baseline” and “trigger” concentrations for benzene are proposed for guard wells within the center of the residual FHC plume (Table 4, Fig. 2). The baseline concentration represents a typical concentration detected in these wells during 1995. These concentrations are representative of the highest residual concentrations within the permeable portions of HSU-3 (the upper and lower steam zones). The trigger concentration represents a significant concentration increase that may lead to non-compliance and may indicate movement or spreading of the residual plume. Prior to remediation, two of the boundary wells, GSW-008 and GSW-009, contained significant levels of FHCs and benzene. Now ground water from these wells meets MCLs and all three wells are located downgradient or crossgradient of the residual FHC plume. The baseline concentration represents a typical concentration detected in these wells during 1995. The trigger concentration is the MCL. The completion specifications for all guard and boundary wells and other TFF HSU-3 wells within the proposed CZ are presented in Appendix A. Well GSW-10 was damaged by steam and will be replaced or destroyed. Well GSW-208 was filled with sand prior to steaming and will be desanded.

Table 4. Contingency Monitoring Plan for maintaining compliance in HSU-3 at TFF.

	Monitoring wells	Benzene (ppb)	
		Baseline concentration	Trigger concentration
Guard wells	GSW-006	300	900
	GSW-013	8.9	27
	GEW-816	210	630
	GSW-215	3.9	12
Downgradient boundary wells	GSW-266	<0.5	1
	GSW-008	<0.5	1
	GSW-009	<1	1

Monitoring of ground water from these wells will occur on a quarterly basis through 1996, and semiannually through 1998. The semiannual sampling will be scheduled to correspond to wet and dry seasons at the LLNL Livermore site. A monitoring report summarizing the analytical results of each monitoring event will be submitted to the SFBRWQCB. If “trigger” concentrations are met or exceeded in any well, immediate resampling will occur. If trigger concentrations are validated by additional sampling results, three responses will occur: 1) the SFBRWQCB, DTSC, and EPA will be notified; 2) ground water monitoring will increase to quarterly status; and 3) resumption of ground water extraction from wells GEW-808 and GEW-816 will be re-evaluated by all parties as a potential remedy. If needed, ground water extraction will resume until baseline concentrations are maintained for two consecutive quarters. The additional quarterly monitoring will continue for two years after the ground water extraction is discontinued to ensure that baseline concentrations are maintained. This plan will ensure that “baseline” concentrations are maintained in all wells.

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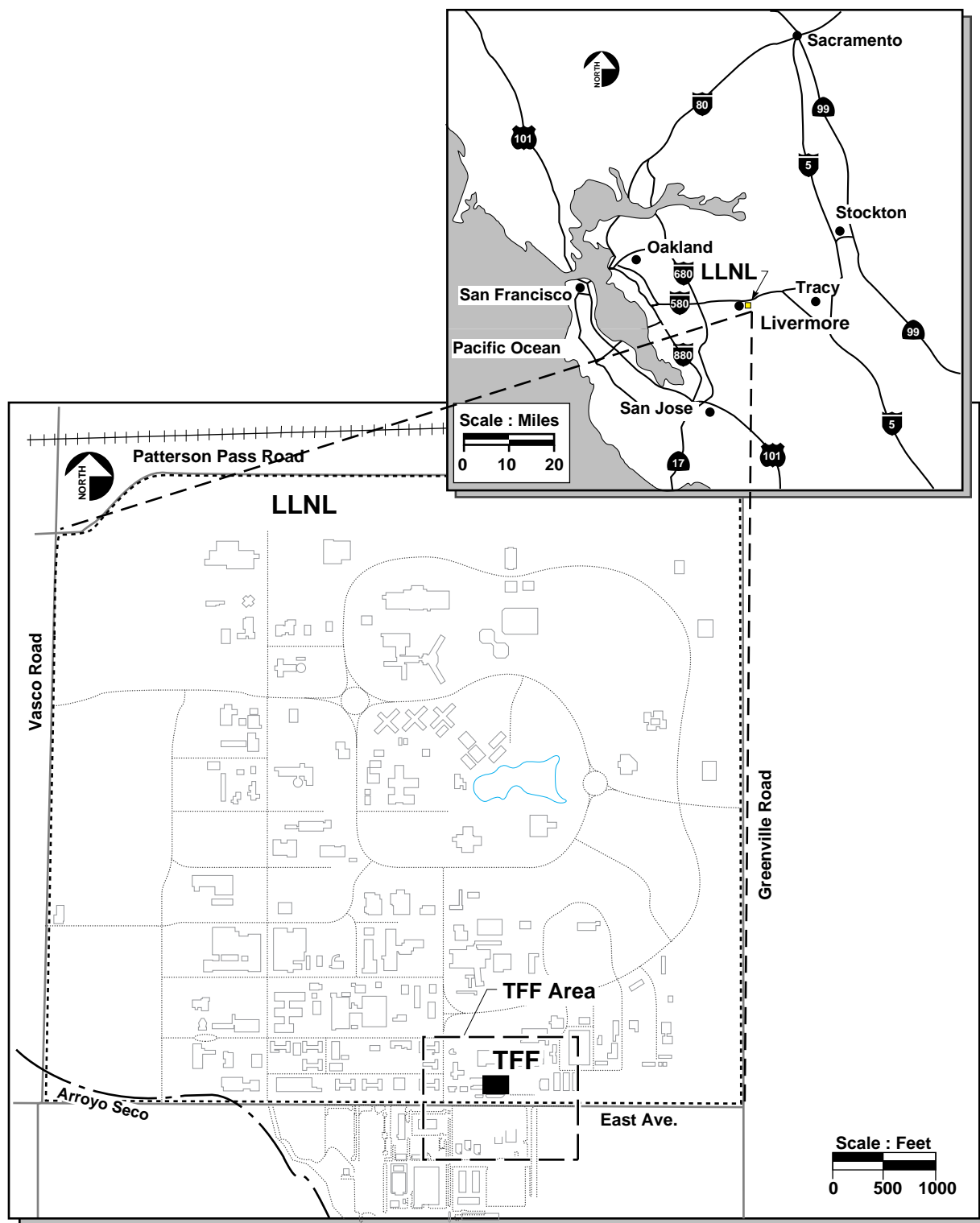
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Figures



ERD-LSR-96-0030

Figure 1. Location of LLNL, TFF and the TFF Area.

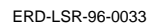
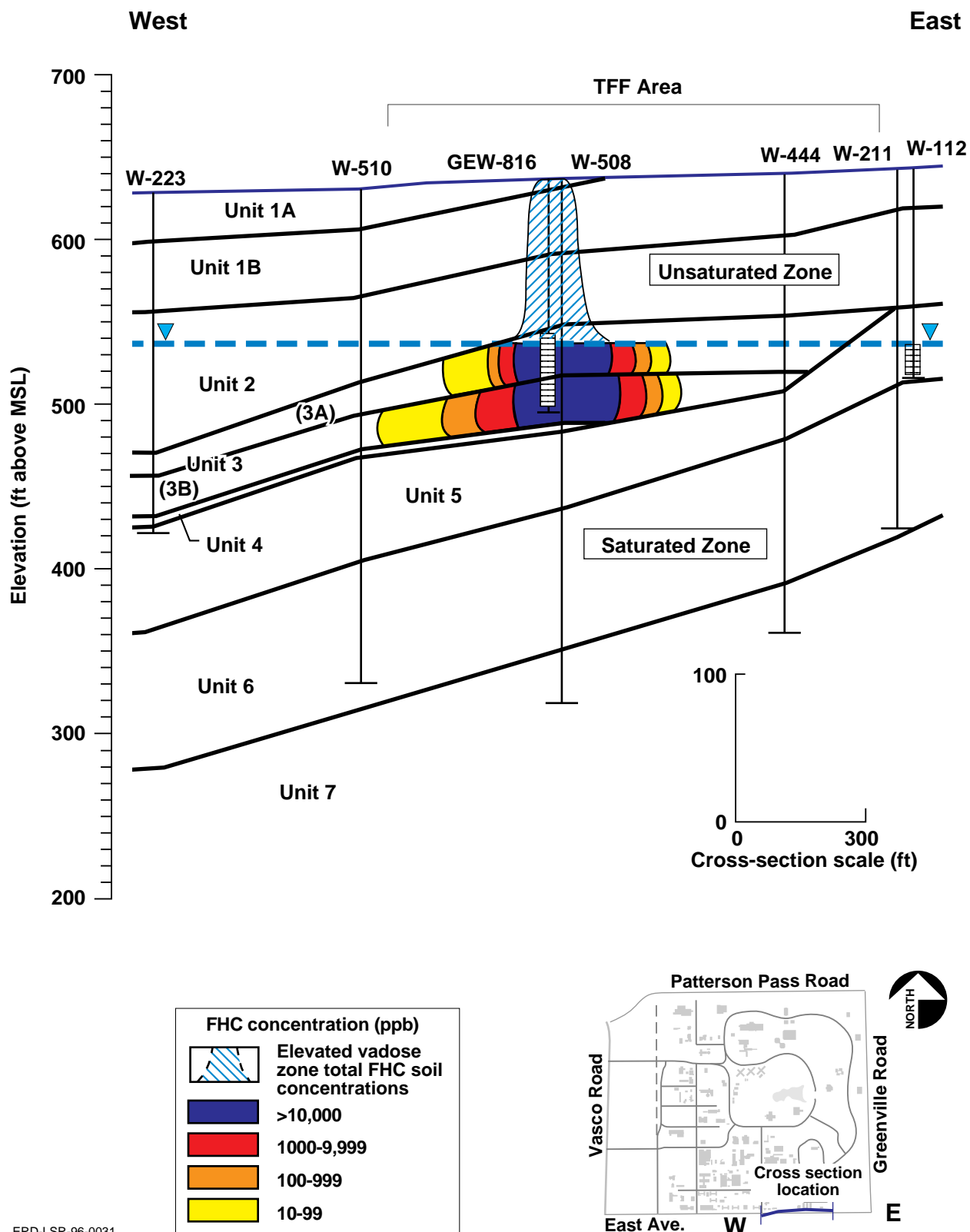
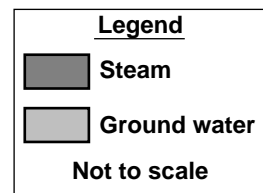
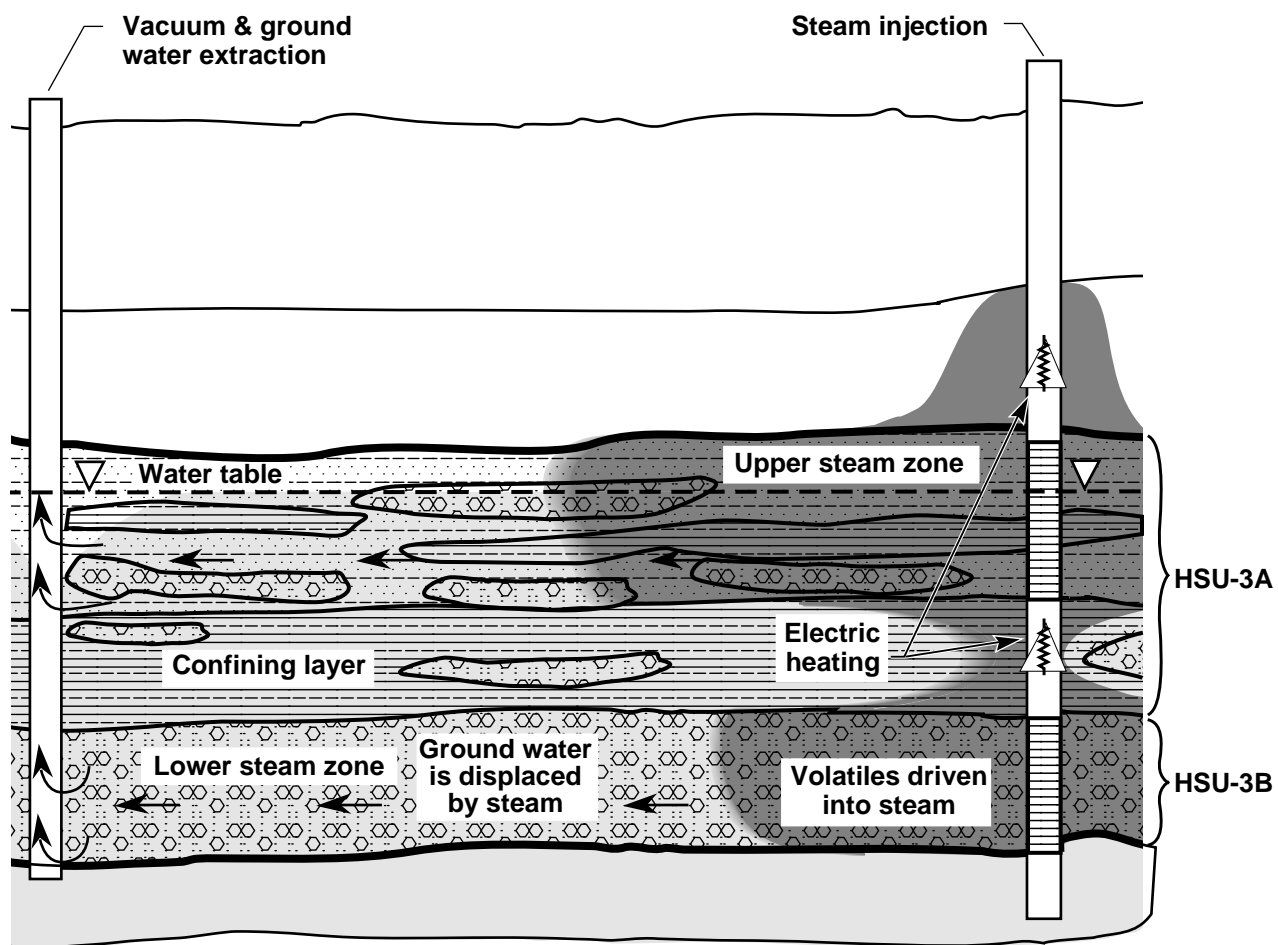


Figure 2. Locations of HSU-3 wells within the central portion of the TFF Area, and proposed containment zone.



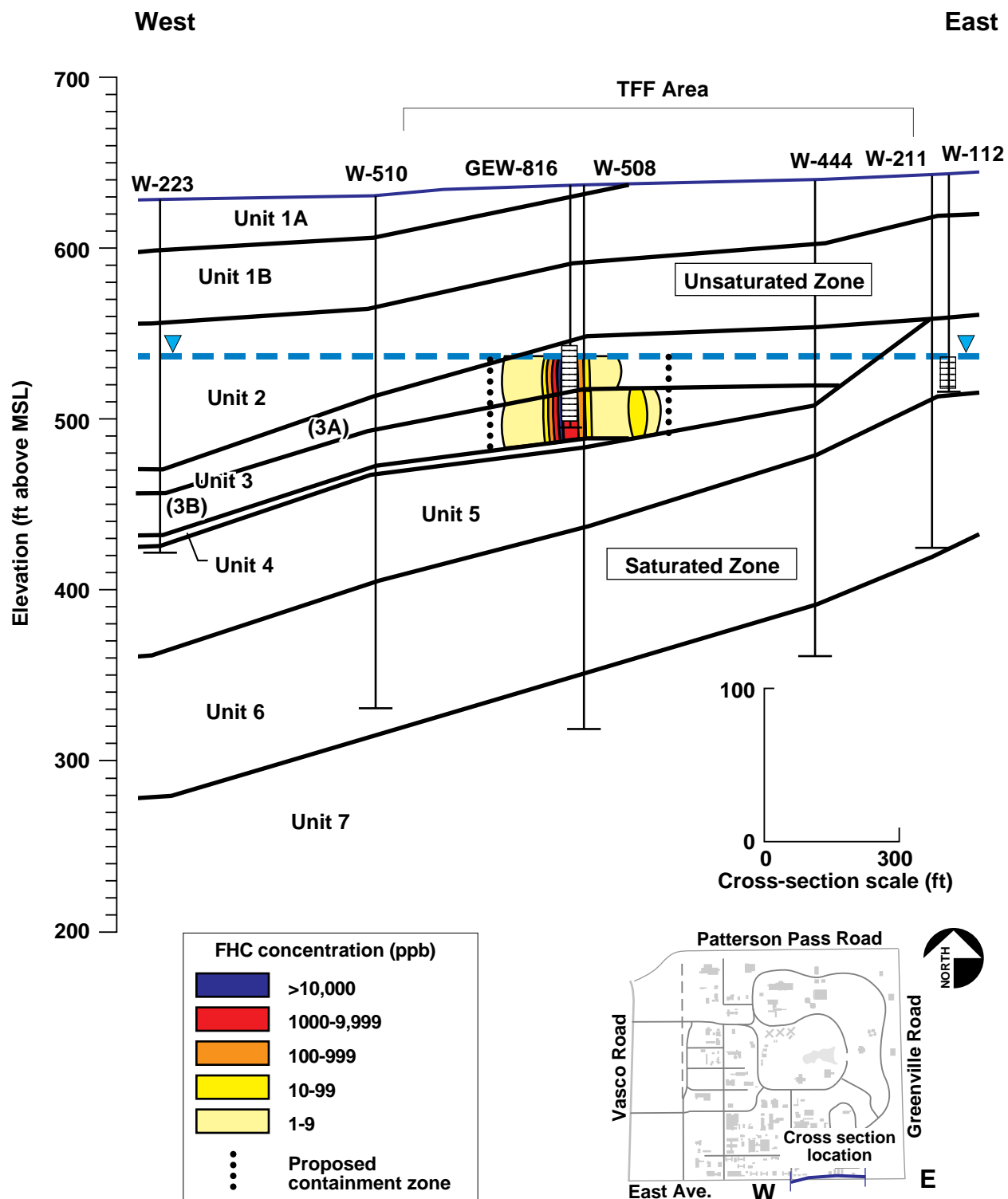
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Figure 3. TFF Area hydrostratigraphic cross section showing historical maximum FHC ground water concentrations in HSU-3 prior to remediation.



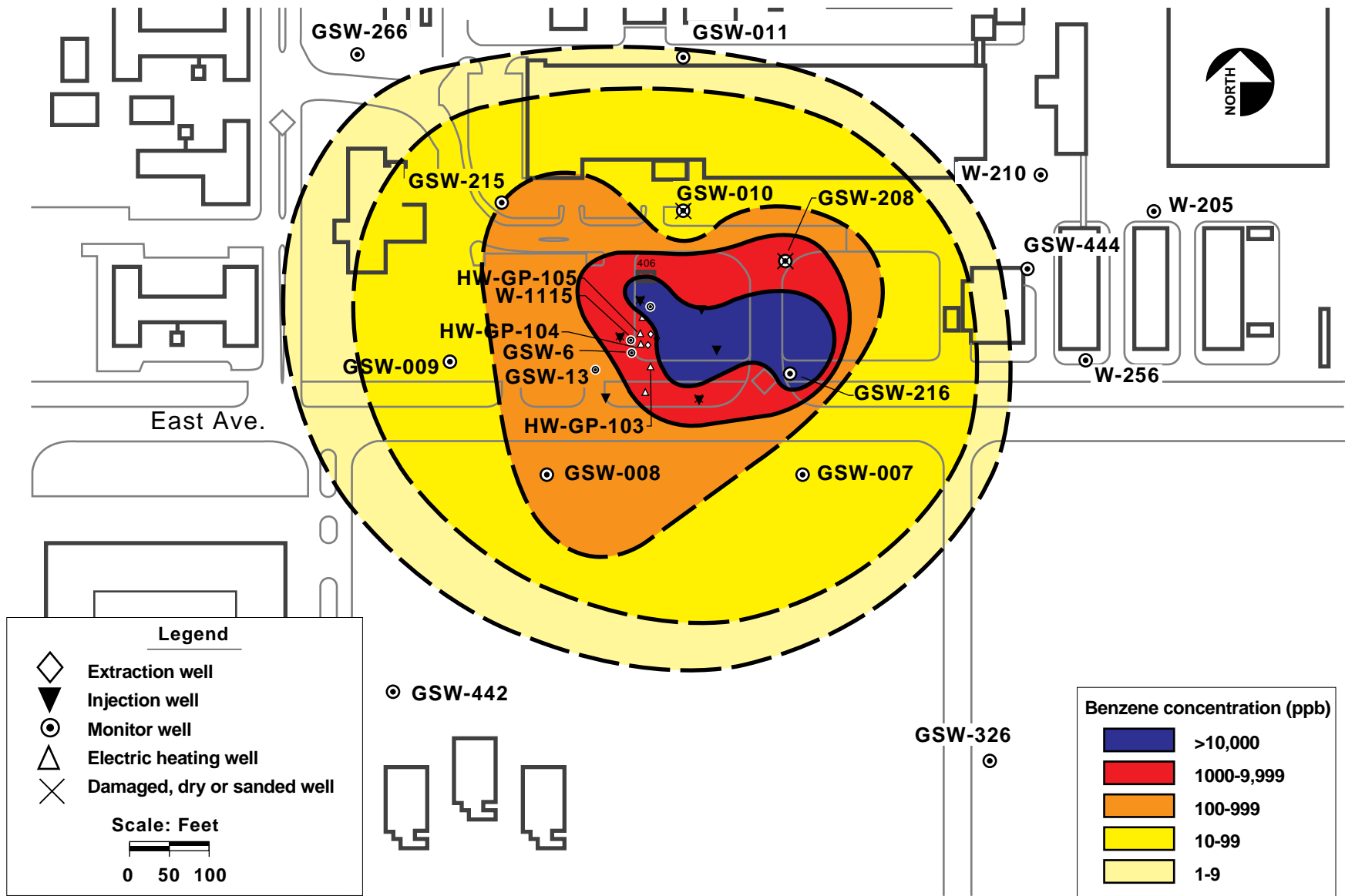
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Figure 4. Relationship between the upper and lower steam zones, the intervening confining layer, and HSU-3.



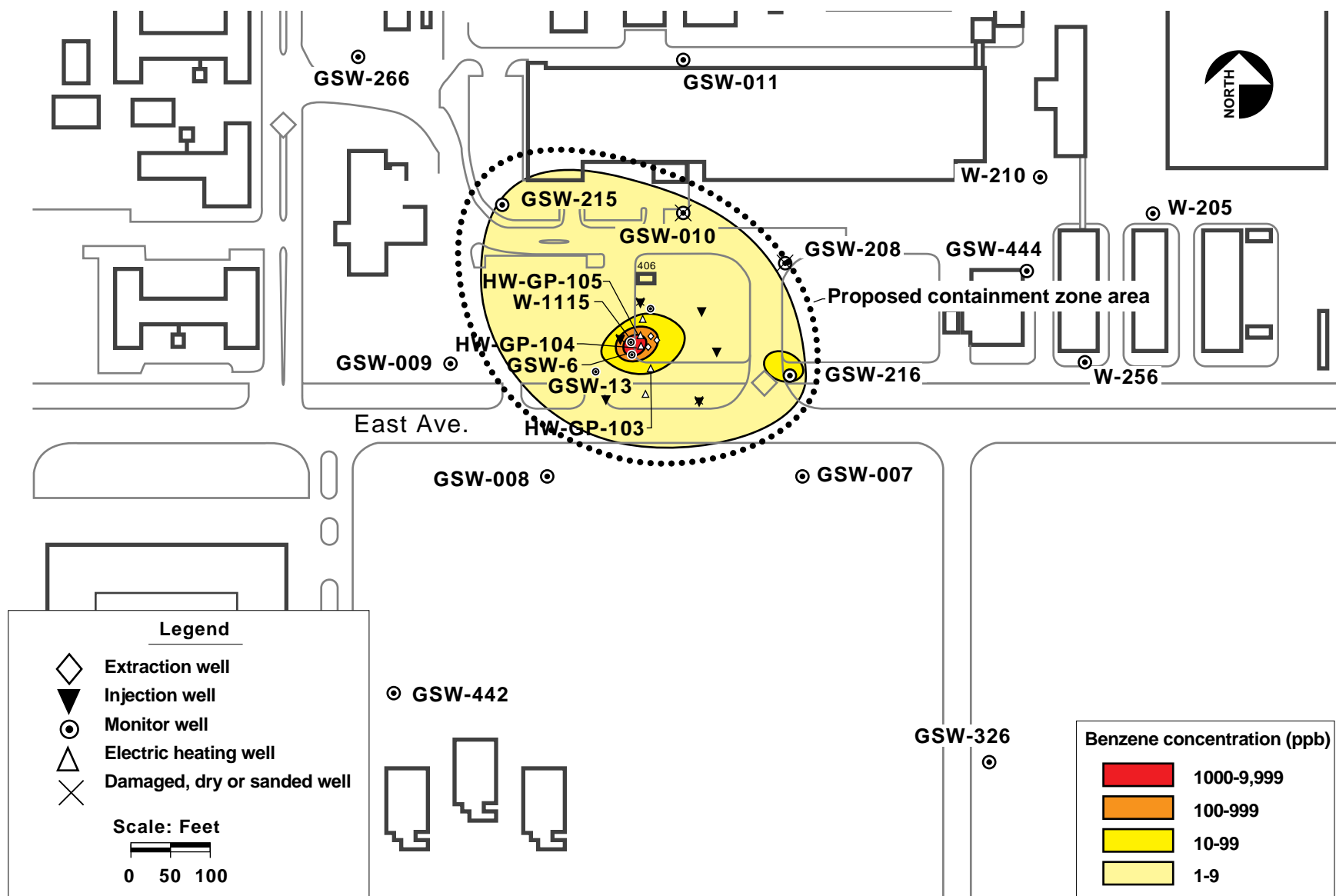
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Figure 5. TFF Area hydrostratigraphic cross section showing FHC ground water concentrations in HSU-3 during 1995 bioremediation study. Note the boundaries of the proposed containment zone.



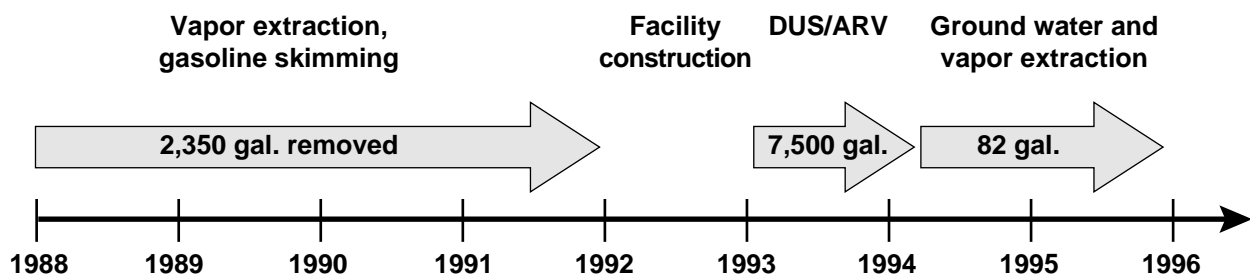
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Figure 6. Maximum historical benzene concentrations in ground water prior to remediation in HSU-3.



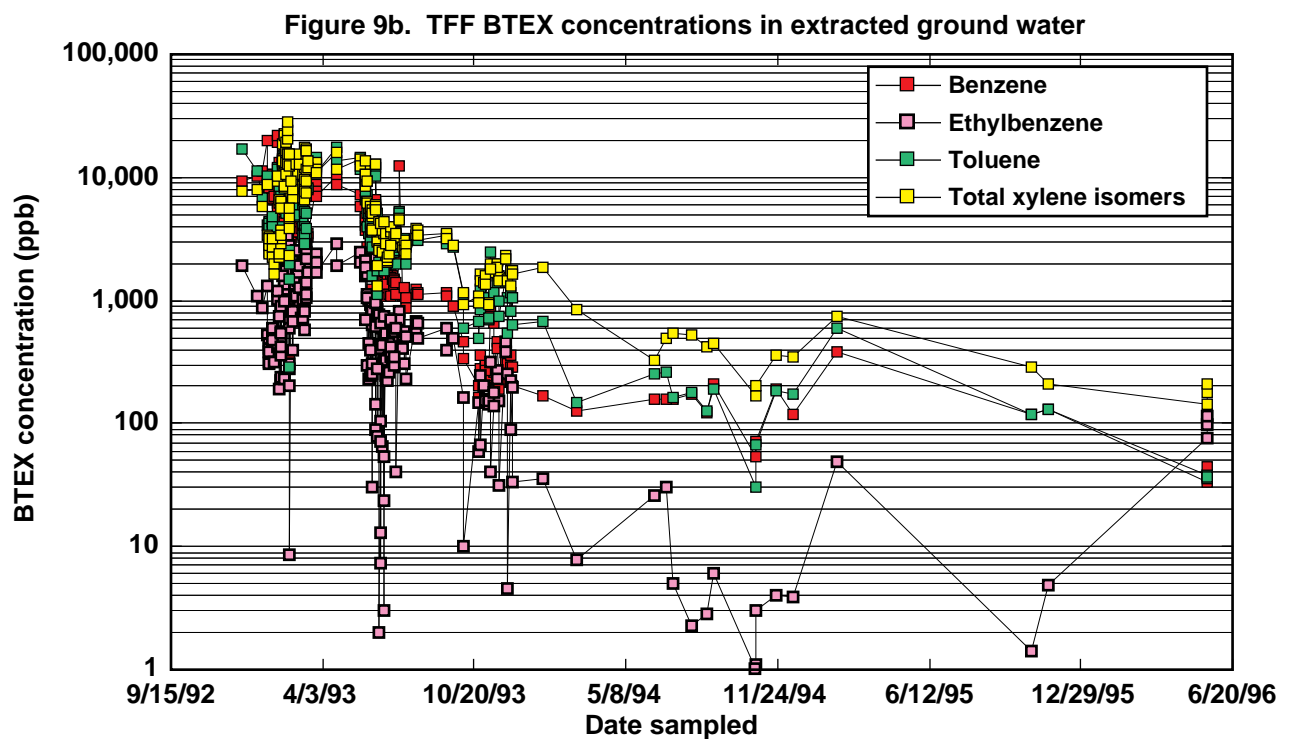
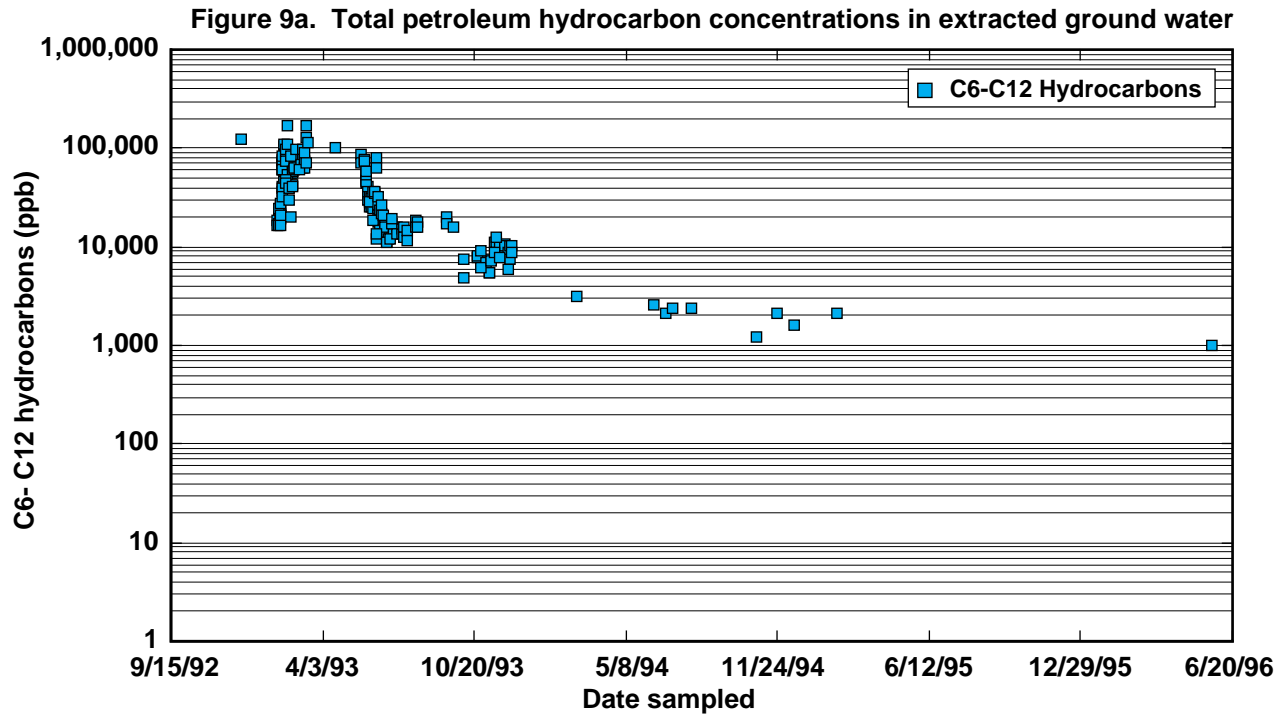
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Figure 7. Maximum benzene concentration in ground water in HSU-3 during 1995 bioremediation study.



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Figure 8. TFF remedial action timeline.



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Figure 9. Total FHC and BTEX concentrations in extracted ground water versus time.

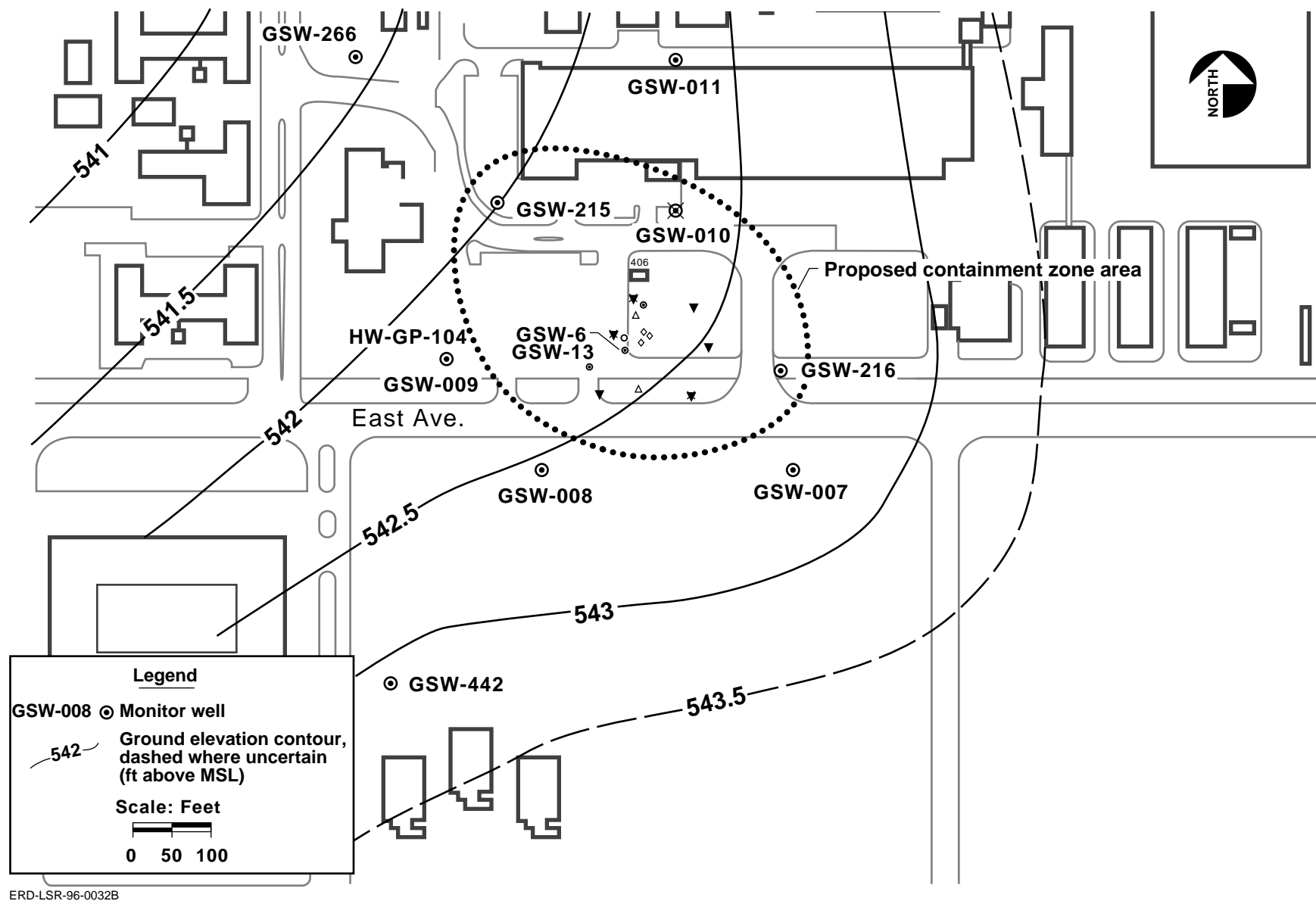


Figure 10. HSU-3B ground water elevation contour map for April 1996.

Appendix A

TFF HSU-3 Monitoring Well and Borehole Completion Data

Table A-1. TFF HSU-3 monitoring well and borehole completion data.

Well/borehole	Well/borehole depth	Screened interval(s) (ft)	Screened zone(s)	Well status
C403-1	77	NA	NA	
C403-2	51	NA	NA	
C403-3	42	NA	NA	
C403-4	42	NA	NA	
C403-5	36.2	NA	NA	
C403-7	51	NA	NA	
C403-8	51	NA	NA	
C403-9	51	NA	NA	
C403-10	76	NA	NA	
GEW-710 ^a	158	94-137	USZ and LSZ	Abandoned
GEW-711	167.5	94-137	USZ and LSZ	
GEW-808 ^{a,b}	150	50-140	USZ and LSZ	
GEW-816 ^{a,b}	161.8	50-140	USZ and LSZ	
GIW-813 ^{a,b}	140.7	67-87 107-127	USZ and LSZ	
GIW-814 ^{a,b}	149.6	86.5-106.5 121-141	USZ and LSZ	Destroyed
GIW-815 ^{a,b}	143	77-97 112.8-132.5	USZ and LSZ	
GIW-817 ^c	150	82-102 121-141	NA	
GIW-818 ^{a,b}	150	82-102 120-140	USZ and LSZ	
GIW-819 ^{a,b}	150	78.6-98.6 121-141	USZ and LSZ	
GIW-820 ^{a,b}	143.3	85-105 112-132	USZ and LSZ	
GSB-1	96	NA	NA	
GSB-2	97	NA	NA	
GSB-3	97	NA	NA	
GSB-4	96	NA	NA	
GSB-6	106	NA	NA	
GSB-14	141	NA	NA	
GSB-801 ^b	143.9	NA	NA	
GSB-802 ^b	148	NA	NA	
GSB-803 ^b	150	NA	NA	

Table A-1. (Continued)

Well/borehole	Well/borehole depth	Screened interval(s) (ft)	Screened zone(s)	Well status
GSB-804 ^b	145.5	NA	NA	
GSB-805 ^b	150	NA	NA	
GSB-806 ^a	140	NA	NA	
GSB-807 ^b	150.5	NA	NA	
GSB-809 ^b	132.5	NA	NA	
GSB-810 ^b	142.3	NA	NA	
GSB-811 ^b	140.1	NA	NA	
GSB-SNL-001 ^b	131	118-131	LSZ	
GSW-1A	208.5	115-130	LSZ	Sanded
GSW-2	113	87-107	USZ	Sanded
GSW-3	115	85-105	USZ	Sanded
GSW-4	112	86-106	USZ	DRY
GSW-5	110	94-104	USZ	Sanded
GSW-6 ^a	212	121-137	LSZ	
GSW-7 ^a	176.6	110.8-123.4	LSZ	
GSW-8 ^a	176.3	127.5-133	LSZ	
GSW-9 ^a	197.2	147-152.5	LSZ	
GSW-10	205.5	114-127.5	LSZ	Damaged
GSW-11	182.5	115-126	LSZ	
GSW-13 ^a	198	125-134.5	LSZ	
GSW-15	148	20.5-28 38-44 50-56 60-64 68-73 77-83 95-105 120-130	Above USZ, USZ, and LSZ	Sanded
GSW-16 ^a	146	23-28 38-43 50-55 61-66 78-83 95-105 120-130	Above USZ, USZ, and LSZ	
GSW-208	211	108-118	LSZ	Sanded
GSW-209	204	113-133	LSZ	Damaged
GSW-215 ^a	213.5	127-133.5	LSZ	

Table A-1. (Continued)

Well/borehole	Well/borehole depth	Screened interval(s) (ft)	Screened zone(s)	Well status
GSW-216 ^a	120.5	110.5-120.5	LSZ	
GSW-403-6	138	90-110	USZ and LSZ	Sanded
HW-GP-001 ^b	120	67-77 103-113	Above USZ and CL	Damaged
HW-GP-002 ^{a,b}	120	68-78 107-117	Above USZ and CL	
HW-GP-003 ^{a,b}	119	66.5-76.5 109-119	Above USZ and CL	
HW-GP-102 ^a	140.0	72.5-133.5	USZ and LSZ	
HW-GP-103 ^a	138.0	71.5-132.5	USZ and LSZ	
HW-GP-104 ^a	138.0	72.2-132.2	USZ and LSZ	
HW-GP-105 ^a	138.0	72.5-132.5	USZ and LSZ	
W-20	134	95-105	USZ	
W-1115 ^a	126.5	108-118	CL	
SVB-GP-001 ^b	20	–	NA	
SVB-GP-002 ^b	21	–	NA	
SVB-GP-004 ^b	21	–	NA	
SVB-GP-006 ^b	20	–	NA	
SVB-GP-008A ^b	90	–	NA	
SVB-GP-009 ^b	20.3	–	NA	
SVB-GP-010 ^b	20	–	NA	
SVB-GP-012 ^b	51	–	NA	
SVB-GP-013 ^b	89	–	NA	
SVB-GP-014 ^b	90	–	NA	
TEP-GP-001 ^b	165	88-97 107-117	USZ and LSZ	Grouted
TEP-GP-002 ^b	161.4	102-112.5 122-133	USZ and LSZ	Grouted
TEP-GP-003 ^b	161.1	124.5-129.5	LSZ	Grouted
TEP-GP-004 ^b	161	96-106 124-134	USZ and LSZ	Grouted
TEP-GP-005 ^b	161	114.5-124.5	LSZ	Grouted
TEP-GP-006 ^b	161	107-127	LSZ	Grouted
TEP-GP-007 ^b	161	115.5-125.5	LSZ	Grouted
TEP-GP-008 ^b	161	100-110 119-129	USZ and LSZ	Grouted

Table A-1. (Continued)

Well/borehole	Well/borehole depth	Screened interval(s) (ft)	Screened zone(s)	Well status
TEP-GP-009 ^b	161.8	98-107 120.5-130.5	USZ and LSZ	Grouted
TEP-GP-010 ^b	161	114.5-124.5	LSZ	Grouted
TEP-SNL-011 ^b	161	98-108	USZ	

Notes:

-- = Data not available.

CL = Confining layer between USZ and LSZ (approximately 110 to 120 ft bgs).

GEW = Gasoline Spill Area extraction well.

GIW = Gasoline Spill Area injection well and electrical resistance heating well.

GSB = Gasoline Spill Area borehole.

GSW = Gasoline Spill Area well.

HW = Gasoline Spill Area electrical resistance heating well.

LSZ = Lower steam zone (approximately 120 to 135 ft bgs).

NA = Not applicable.

SVB = Soil vapor borehole.

TEP = Gasoline Spill Area imaging/temperature well.

USZ = Upper steam zone (approximately 80 to 110 ft bgs).

W = Well.

^a HSU-3 wells within or immediately adjacent to the proposed containment zone.^b DUS boreholes and wells.^c Faulty completion, well abandoned.

Appendix B

Concentrations of Hydrocarbons and BTEX Compounds in TFF Extracted Ground Water

Table B-1. Concentrations of hydrocarbons and BTEX compounds in TFF extracted ground water.

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
12/17/92	123,000				
12/18/92		9,450	1,890	16,900	7,690
01/06/93		10,100	1,100	11,300	7,850
01/14/93		11,400	874	6,740	5,820
01/19/93		19,710	1,296	10,120	8,790
01/20/93		8,520	530	4,090	3,420
01/21/93		7,760	386	3,540	2,950
01/21/93		7,660	380	3,450	2,840
01/21/93		9,760	470	4,410	3,280
01/21/93		9,570	442	4,270	3,160
01/22/93		6,730	319	2,970	2,460
01/22/93		6,790	309	2,950	2,410
01/22/93		8,730	407	3,820	2,790
01/26/93		10,594	541	4,393	2,624
01/26/93		10,508	572	4,384	2,731
01/26/93		9,391	597	4,797	3,177
01/27/93		9,554	470	3,951	2,414
01/27/93		8,828	393	3,647	2,257
01/28/93		6,686	320	2,884	1,645
01/28/93		7,017	377	3,136	1,956
02/01/93		6,158	376	2,888	2,790
02/03/93	18,600	19,170	1,205	11,600	9,282
02/03/93	16,800	21,960	1,023	11,970	10,216
02/03/93	24,600	5,810	421	3,110	2,450
02/04/93	16,900	13,170	1,012	8,470	6,687
02/04/93	16,300	11,470	734	6,970	6,145
02/04/93	19,200	4,712	368	2,673	2,226
02/04/93	20,100	4,380	188	2,440	2,371
02/05/93	21,100	5,020	485	3,850	3,270
02/05/93	19,300	4,440	221	3,030	2,888
02/05/93	27,600	4,853	501	3,728	3,238
02/05/93	16,500	4,485	222	3,181	3,229
02/06/93	20,600	4,820	551	3,950	3,620
02/06/93	21,900	4,540	360	3,460	3,490

Table B-1. (Continued)

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
02/06/93	25,200	4,699	496	3,923	3,672
02/06/93	20,700	4,306	239	3,220	3,344
02/07/93	41,600	5,250	839	6,420	6,290
02/07/93	36,000	4,810	546	5,670	5,950
02/07/93	39,200	5,440	909	7,040	6,380
02/07/93	32,300	4,820	419	5,770	5,690
02/08/93	71,800	5,830	2,220	11,600	12,840
02/08/93	81,600	5,970	2,820	15,200	18,860
02/08/93	75,600	6,180	2,350	12,200	13,250
02/08/93	60,600	5,710	1,580	10,300	11,630
02/09/93	73,400	6,210	2,500	12,300	14,050
02/09/93	60,400	5,980	2,000	12,200	14,110
02/09/93	69,500	5,995	2,375	11,755	13,427
02/09/93	60,900	6,029	1,797	11,962	13,844
02/10/93	61,100	4,710	1,920	9,300	11,090
02/10/93	48,700	4,820	1,220	9,470	11,730
02/10/93	51,600	4,406	1,897	8,757	11,000
02/10/93	45,500	3,703	231	6,405	10,287
02/11/93	105,600	7,943	3,772	16,469	22,540
02/11/93	111,400	7,429	2,074	15,074	22,016
02/12/93	47,300	3,510	1,340	5,710	8,330
02/12/93	44,800	3,360	982	5,520	8,370
02/12/93	95,600	7,192	3,610	17,204	20,100
02/12/93	88,800	7,107	2,988	16,971	19,023
02/13/93	55,600	2,983	1,385	5,109	8,638
02/13/93	63,200	3,056	1,653	6,193	11,423
02/13/93	62,700	3,474	1,727	6,505	10,617
02/13/93	77,000	3,999	2,549	10,697	16,306
02/14/93	69,300	2,908	2,438	8,168	14,670
02/14/93	72,800	2,915	2,321	8,790	14,946
02/14/93	79,200	2,302	2,147	7,542	13,119
02/14/93	68,700	2,229	2,098	7,744	13,901
02/14/93	66,400	2,717	2,108	7,630	12,641
02/14/93	74,400	2,905	2,368	9,491	15,427

Table B-1. (Continued)

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
02/15/93	54,600	2,330	3,350	9,310	20,380
02/15/93	75,200	2,010	2,360	7,580	15,490
02/16/93	167,700	4,888	3,780	11,811	24,260
02/16/93	110,600	4,288	3,428	12,142	28,668
02/17/93	39,300	977	596	2,200	4,459
02/17/93		700	203	1,500	5,640
02/17/93	30,200	1,310	686	2,560	4,800
02/17/93		921	279	1,990	7,430
02/18/93	71,000	3,232	2,847	11,236	15,717
02/18/93		2,329	1,065	7,227	12,323
02/18/93	20,100	792	309	1,475	2,344
02/18/93		342	8.7	292	3,820
02/19/93	69,400	6,209	1,455	11,593	8,358
02/19/93		5,138	964	9,463	9,337
02/19/93	56,800	3,378	1,188	6,714	7,846
02/19/93		3,000	829	6,060	7,470
02/20/93	83,600	6,600	1,600	12,000	9,550
02/20/93		5,720	1,200	10,200	8,980
02/20/93	61,800	6,377	1,548	11,535	9,348
02/20/93		5,840	1,185	10,183	9,391
02/21/93	66,700	6,748	1,704	12,142	10,443
02/21/93		5,896	1,225	10,325	9,362
02/21/93	42,300	4,235	1,140	7,714	6,819
02/21/93		3,657	392	5,991	7,401
02/22/93	40,300	6,010	1,410	10,200	8,750
02/22/93		5,240	811	8,560	8,830
02/22/93	56,700	5,530	1,420	9,280	8,660
02/22/93		4,630	300	6,850	7,910
02/23/93	57,900	5,170	1,670	9,710	9,900
02/23/93		4,640	1,090	8,370	9,130
02/23/93	59,100	5,230	1,620	9,480	9,660
02/23/93		4,620	670	7,720	9,250
02/24/93	61,800	4,629	1,676	8,970	9,900
02/24/93		4,290	1,010	7,900	9,250

Table B-1. (Continued)

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
02/24/93	65,600	4,747	1,855	9,595	10,93
02/24/93		4,349	1,173	8,459	9,934
02/25/93	63,300	1,669	1,361	4,819	9,572
02/25/93		1,818	799	4,924	9,731
02/26/93	62,600	3,964	1,507	7,697	9,422
02/26/93		3,557	1,073	6,888	8,968
02/27/93	98,600	5,218	2,546	11,269	15,346
02/27/93		4,566	1,548	9,532	12,875
02/28/93	77,600	4,790	1,680	9,090	10,430
02/28/93		4,230	986	7,760	9,670
03/01/93	66,600	4,724	1,452	8,239	9,028
03/01/93		4,122	942	7,203	8,976
03/02/93	81,800	4,194	1,920	8,794	12,762
03/02/93		3,711	905	6,670	9,079
03/03/93	61,400	4,089	1,289	6,954	8,520
03/03/93		3,607	803	6,205	8,580
03/04/93	68,600	3,899	1,292	6,810	8,719
03/04/93		3,503	716	5,718	7,756
03/05/93	85,300				
03/06/93	63,600	2,402	1,193	5,076	8,355
03/06/93		2,383	1,025	5,445	10,211
03/07/93	80,800	1,430	1,100	4,040	8,410
03/07/93		1,310	721	3,400	6,780
03/08/93	99,300	1,510	2,392	5,942	15,102
03/08/93		1,101	1,354	4,241	10,663
03/09/93	91,700	1,656	2,499	7,775	14,963
03/09/93		2,223	2,735	10,511	17,693
03/10/93		1,500	1,500	5,300	12,000
03/10/93		1,400	920	4,000	8,500
03/10/93		907	581	2,909	6,557
03/10/93	62,000	985	978	3,479	7,541
03/10/93	72,600	1,010	1,230	3,760	9,490
03/10/93		1,040	826	3,430	7,600
03/11/93	70,500	1,180	1,050	3,470	7,520

Table B-1. (Continued)

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
03/11/93		1,080	1,110	3,900	9,440
03/12/93	130,500	1,658	2,469	7,634	16,395
03/12/93		1,312	1,398	5,173	11,481
03/13/93	169,300	6,980	2,870	14,700	16,820
03/13/93		5,039	2,188	12,506	16,505
03/14/93	114,500	3,480	1,870	8,020	11,910
03/14/93		3,249	1,693	8,262	13,662
03/26/93		8,747	2,362	14,570	13,371
03/26/93		7,858	1,956	12,551	12,087
03/26/93		7,759	2,052	12,802	11,779
03/26/93		6,911	1,715	11,071	10,795
04/20/93	100,000	10,138	2,874	17,510	15,862
04/20/93		8,626	1,891	13,694	11,547
05/22/93	85,000	7,271	2,495	14,421	14,052
05/23/93	72,100	5,846	2,030	11,755	12,343
05/28/93	76,700	6,093	2,147	12,339	12,335
05/28/93	74,200	5,891	2,133	12,482	13,651
05/29/93	56,100	5,075	1,886	9,750	10,614
05/29/93	59,200	4,706	1,577	9,029	10,638
05/30/93	47,700	4,126	1,604	7,801	9,093
05/30/93	43,800	3,688	696	6,553	8,580
05/31/93	54,700	4,001	1,645	7,265	9,352
05/31/93	46,100	3,898	1,050	6,610	9,277
06/01/93	40,300	2,709	1,114	5,156	6,291
06/01/93	34,000	2,421	301	4,027	6,104
06/02/93	35,800	2,496	1,068	4,755	5,914
06/02/93	29,500	2,300	228	3,618	5,544
06/03/93	33,000		1,017	4,249	5,669
06/03/93	25,400	2,000	446	3,521	5,536
06/04/93	33,300	2,142	1,053	4,285	6,057
06/04/93	29,000	1,882	247	2,955	5,796
06/05/93	33,700	1,820	918	3,690	5,272
06/05/93	27,400	1,676	398	3,014	5,265
06/06/93	30,800	1,801	815	3,595	4,981

Table B-1. (Continued)

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
06/06/93	25,500	1,627	305	2,755	4,875
06/07/93	24,300	1,593	641	3,024	3,859
06/07/93	18,300	1,213	30	1,607	3,768
06/08/93	36,400	2,517	933	4,748	5,467
06/08/93	29,700	2,306	252	3,621	5,147
06/10/93	34,300	3,148	1,002	5,686	5,905
06/10/93	26,700	2,784	88	4,352	5,501
06/11/93	36,000	3,531	961	5,626	5,723
06/11/93	28,500	3,120	145	4,467	5,448
06/12/93	80,100	6,538	2,172	11,875	12,941
06/12/93	64,100	6,303	610	10,398	12,934
06/13/93	11,900	1,138	280	1,739	1,332
06/13/93	13,400	987	79	1,112	1,922
06/14/93	32,300	3,355	830	5,069	3,103
06/14/93	25,900	3,070	649	4,588	2,971
06/15/93	25,800	2,820	720	4,363	2,653
06/15/93	22,900	2,593	402	3,938	2,576
06/15/93	26,900	2,801	702	4,348	3,957
06/16/93	24,400	2,665	759	4,192	4,354
06/16/93	17,500	2,042	2	2,039	3,561
06/17/93	23,300	2,206	106	3,970	4,011
06/17/93	16,600	1,776	13	2,459	3,246
06/18/93	22,000	2,105	745	4,032	4,238
06/18/93	16,900	1,640	7.3	2,541	3,280
06/19/93	26,300	1,781	650	3,680	3,696
06/19/93	16,300	1,543	71	2,839	3,065
06/20/93	21,100	1,606	587	3,803	3,428
06/20/93	18,000	1,456	66	3,007	3,313
06/21/93	14,100	1,103	431	2,347	2,452
06/21/93	18,600	1,665	741	4,022	4,341
06/21/93	17,300	1,078	24	2,153	2,986
06/22/93	16,200	1,465	548	2,974	3,196
06/22/93	13,700	1,214	3	1,770	2,999
06/23/93		1,243	336	2,614	3,076

Table B-1. (Continued)

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
06/23/93	17,900	1,271	593	2,925	3,503
06/23/93	15,700	1,297	53	2,516	3,453
06/24/93	16,000	1,530	542	3,102	3,116
06/24/93	14,200	1,362	306	2,636	2,940
06/25/93	15,700	1,727	616	3,202	3,510
06/25/93	13,900	1,742	326	2,735	2,946
06/26/93	12,700	1,701	506	2,670	2,850
06/26/93	11,100	1,468	247	2,054	2,308
06/27/93	12,100	1,886	358	2,510	2,018
06/27/93	11,100	1,620	224	2,086	2,079
06/28/93	13,000	1,786	369	2,570	2,101
06/28/93	12,200	1,563	261	2,188	2,229
06/30/93	13,200	1,358	447	2,474	2,586
06/30/93	11,800	1,114	260	1,974	2,413
07/01/93	15,500	1,249	477	2,532	2,764
07/01/93	14,200	1,095	345	2,305	2,997
07/02/93	19,000	1,720	689	3,930	3,911
07/02/93	17,300	1,519	425	3,253	3,592
07/03/93		1,601	565	3,386	3,184
07/03/93		1,389	311	2,603	3,019
07/04/93	16,000	1,500	541	3,205	3,040
07/04/93	13,900	1,318	315	2,580	3,044
07/05/93	14,800	1,402	512	3,034	2,868
07/05/93	13,300	1,278	285	2,471	2,876
07/06/93		1,473	559	3,295	3,134
07/06/93		1,326	297	2,554	3,056
07/07/93		1,436	590	3,318	3,302
07/07/93		1,287	345	2,701	3,434
07/09/93	15,900	1,398	594	3,366	3,330
07/09/93	13,500	1,124	41	1,955	3,528
07/12/93		2,082	821	5,288	4,591
07/12/93		12,267	704	5,061	4,441
07/16/93	15,200	1,150	521	2,990	2,905
07/16/93	13,300	1,070	404	2,740	2,720

Table B-1. (Continued)

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
07/19/93	15,600	1,270	558	3,160	3,090
07/19/93	12,400	1,090	308	2,620	2,547
07/22/93	14,600	1,050	508	2,730	2,783
07/22/93	11,600	877	228	1,960	2,392
08/03/93	18,400	1,246	684	3,432	3,810
08/03/93	16,100	1,136	549	3,118	3,410
08/05/93	17,600	1,175	661	3,298	3,725
08/05/93	15,600	1,108	489	3,047	3,431
09/13/93	20,200	1,150	590	3,410	3,500
09/13/93	17,200	1,100	398	2,930	3,200
09/22/93	15,900	904	488	2,680	2,767
10/05/93	7,360	459	164	1,135	1,145
10/05/93	4,790	332	10	601	920
10/25/93	7,930	204	149	674	1,096
10/25/93	8,070	161	60	497	945
10/28/93	9,080	358	247	1,230	1,643
10/28/93	6,210	283	68	851	1,441
11/01/93		276	203	1,058	1,386
11/04/93	7,330	309	156	985	1,580
11/04/93	6,930	269	152	917	1,363
11/09/93	5,420	240	143	703	947
11/09/93	5,560	245	155	711	940
11/11/93	7,490	843	316	2,464	1,985
11/11/93	7,090	753	41	1,794	1,778
11/15/93	11,100	654	137	1,860	1,684
11/15/93	8,690	265	181	1,150	2,001
11/18/93	12,500	456	269	1,600	1,960
11/18/93	11,000	409	234	1,410	1,878
11/22/93	10,000	250	154	998	1,590
11/22/93	7,670	188	31	737	1,421
11/29/93	10,800	343	459	1,520	2,325
11/29/93	10,300	324	387	1,380	2,196
12/03/93	8,700	308	254	1,042	1,511
12/03/93	5,900	215	4.5	534	1,434

Table B-1. (Continued)

Sampled date	C6-C12 Hydrocarbons (µg/L)	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total xylene isomers (µg/L)
12/06/93	10,300	357	222	1,170	1,725
12/06/93	7,580	286	88	804	1,314
12/09/93	10,400	292	197	1,036	1,721
12/09/93	8,730	206	34	626	1,627
01/19/94		170	36	683	1,866
03/04/94	3,142	125	7.7	150	846
06/14/94	2,620	157	26	257	327
06/29/94	2,080	156	30	265	489
07/08/94	2,340	158	5	165	544
08/03/94	2,385	172	2.3	177	530
08/23/94		124	2.8	125	427
09/01/94		209	6	189	448
10/27/94		54	1	30	170
10/27/94	1,220	72	3	68	206
11/22/94	2,120	192	4	186	361
12/15/94	1,620	117	3.9	176	344
02/09/95	2,140	382	48.4	594	736
03/18/95					
10/13/95					
10/25/95		120	1.4	120	290
11/15/95		130	4.9	130	210

Attachment 1

M e m o r a n d u m

DRAFT

To: Board and Local Agency Staff
Distribution list

Date: October 20, 1994
File No. 1210.49 (DDD)

From: Steven R. Ritchie, Executive Officer
REGIONAL WATER QUALITY CONTROL BOARD
San Francisco Bay Region
2101 Webster St., Suite 500
Oakland, CA 94612

Subject: Implementation of Ground Water Non-Attainment Areas

With the adoption of the Ground Water Basin Plan amendments of August 17, 1994, the Regional Board has again confirmed their approval of the concept and implementation of Ground Water "Non-Attainment Areas". The Basin Plan amendments must yet be approved by the State Water Board and the Office of Administrative Law before Non-Attainment Areas can be cited as policy. However, awaiting State Water Board and OAL approval, we can implement the non-attainment provisions of the Basin Plan amendments for ground water cleanups on a case-by-case basis provided the record substantiates the rationale for utilizing the non-attainment option for the particular site.

This memorandum is intended to provide the assistance and direction to Board staff and local agencies that will allow the use of the non-attainment provisions of the Board's Basin Plan for any site that qualifies. I expect all regulatory agency staff to aggressively insure that all Dischargers are made aware of the non-attainment option and are provided with a copy of this memorandum. I strongly encourage all staff to look for opportunities to use the non-attainment option.

There are many areas where this memo requires decisions that involve professional judgement, such as on cost-effectiveness, plumes that cross property boundaries, limited risk, and no significant migration etc. It is our belief that these decisions will become easier as we start working through these decisions on specific sites.

It is recommended that a Discharger, after reviewing this memorandum, and believing that it's site qualifies for consideration, contact either the local oversight agency or the Regional Board. The Discharger will present the available information that supports its findings and will receive a preliminary response from the regulatory agencies. The regulatory agencies could indicate that the site does or does not qualify; appears to qualify or not to qualify; and indicate in what area they have concerns. The Discharger could then make a decision to present a formal request, with all the supporting data, to be considered under the non-attainment provisions. A Joint meeting with the local agency and the Regional Board could be requested, if necessary, to discuss the site.